Procuring Architectural and Engineering Services for Energy Efficiency and Sustainability

A Resource Guide for Federal Construction Project Managers

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Introduction

> What usually comes first is the contract.
> *Benjamin Disraeli, 1804-1881*

Many Federal agencies have developed and embraced the principles of sustainable design. These principles strike a balance between the need to fulfill an agency's mission in cost-effective buildings and the need to protect workers, the environment, and other resources. Agencies have the leverage to convert these principles into effective design practices through the procurement of architectural and engineering (A/E) services for energy-efficient, sustainable new construction.

The two most important elements in the procurement process are the selection criteria and the statement of work. This is because a capable, enthusiastic design team and the right work plan virtually assure a successful, energy-efficient, sustainable design. The result would be compromised if principles of sustainability were not made enforceable ("given teeth") in each A/E contract. Therefore, this guide was prepared to be a resource for Federal construction project managers and others who want to integrate the principles of sustainable design into the procurement of professional building design and consulting services.

To economize on energy costs and improve occupant safety, comfort and health, you can incorporate daylighting, energy efficiency, renewable energy, and passive solar design into all projects in which these elements are technically and economically feasible. But how do you do that? The information presented here will help you to begin and to manage the inclusion of sustainable design in the procurement process. The section on establishing selection criteria contains key elements to consider before you actually select an A/E firm. The section on preparing the statement of work discusses the broad spectrum of sustainable design services that an A/E firm can provide for your Federal project.

The Federal Context

As the world's largest consumer of energy, the Federal Government has a tremendous opportunity to save money spent on energy every year. In fiscal year (FY) 2000, for example, the Government spent \$3.39 billion on energy for buildings and facilities, or \$1.11 per square foot (ft^2) per year. Data show that about 1.39 quadrillion British thermal units (Btu) of primary energy were consumed in FY 2000: 0.63 for buildings and 0.76 for vehicles and equipment.

However, the Federal Government has made considerable progress in reducing this energy use and cost. Building energy use fell from 139 kBtu/ft^2/year in 1985 to 121 kBtu/ft^2/year in 1995—less than the National Energy Conservation Policy Act goal of 126 kBtu/year. Energy use was reduced further by the year 2000 to 106.7 kBtu/ft^2/year. But according to the Department of Energy's (DOE's) Federal Energy Management Program (FEMP), more progress is needed if the Government is to meet the goals of Executive Order 13123 and reach 97.6 kBtu/ft^2/year by 2005 and 90.6 kBtu/ft^2/year by 2010.

Much of the reduction in energy use can be attributed to retrofit projects in existing Federal buildings. In rare instances, new buildings use more energy than the old ones they replace. For example, new military housing in temperate Hawaii includes air-conditioning, while older housing relies on natural ventilation. Similarly, office automation and space-conditioning needs can increase the amount of energy consumed in new commercial buildings. But in general the superior energy efficiency of new buildings contributes to Federal energy reduction goals. This is because improvements in equipment efficiency and material properties usually result in new buildings that consume less energy than older ones.

Dozens of Federal agencies construct, renovate, and maintain thousands of buildings in a wide range of climates and conditions. Thus, construction and maintenance costs are considerable. The Federal Government spent $130 million in FY 2002 on energy conservation retrofits, but more than $16.5 *billion* on all new construction the same year—$5.4 billion for defense-related buildings and the remainder for civilian agencies, as shown in Table 1. Clearly, it is very important to leverage this investment toward better energy efficiency and sustainability. "Doing it right the first time" is much more cost-effective than retrofitting a building for greater efficiency later.

Table 1. Value of New Federal Construction (FY 2002)

Type of Federal Construction	**Value Put in Place** (in millions)
Residential	$ 1,493
Office	2,422
Commercial	903
Health Care	1,391
Educational	1,403
Public Safety	1,601
Amusement and Recreation	655
Transportation	1,796
Power	259
Highway and Street	685
Conservation and Development	2,576
Manufacturing	140
Total Federal Construction	**$16,563**

Source: U.S. Census, Construction Expenditures Branch of the Manufacturing and Construction Division, 2003, Value of New Construction Put in Place; see http://www.census.gov/prod/2002pubs/c30-0208.pdf.

Achieving superior building performance requires a comprehensive approach. It begins during the selection of A/E professionals and continues through programming and the development of schematics, design, and construction documents. It culminates in building construction and commissioning. Superior building performance must then be sustained by conscientious maintenance and confirmed by monitoring.

The Value of Integrated Design

Buildings have always been designed to achieve their functional mission. Good building design has also addressed aesthetics, cost and durability issues. Today, however designers of Federal buildings are realizing the importance of addressing other considerations as well including accessibility for the disabled, historical preservation, environmental impacts, regulations and code requirements, and, more recently, sustainability.

Treating such additional requirements as “add-ons” to the basic mission can increase the cost and compromise the effectiveness of a design. But considering them early in the design process—in an integrated manner—allows designers to meet multiple objectives at little or no additional cost. For example, specifying a wheel chair ramp *in addition* to stairs can increase total costs, but specifying a ramp *instead* of stairs can reduce costs.

Designers have also demonstrated that features intended to improve the sustainability of a building can enhance its mission in other ways. For example, daylighting is sometimes considered an added sustainability feature. But studies show that integrating daylighting into a design actually reduces operating costs, improves occupants’ morale and productivity, and augments safety and security by providing light during power outages.

Incorporating low-energy and climate-responsive strategies requires a unique perspective—that of whole-building performance. This means balancing energy flows like heating, cooling, ventilation and lighting requirements with a desire to incorporate energy efficiency and renewable energy. It also means understanding the interactions among architectural decisions such as orientation, the amount and location of glazing, and the placement of thermal mass and insulation, as well as their combined effect on heating, cooling, and lighting. Evaluating complex interactions and selecting among options requires some type of analysis. But evaluation tools in the past have been cumbersome and expensive. However, a new generation of software (for example, *ENERGY-10* or *eQUEST®*) makes this process both easier and more accurate.

Because purposes and locations of Federal building projects are diverse, it is not possible to define a single set of procurement specifications that apply to all projects or all agencies. Nevertheless, by considering the process in which these specifications are developed, agencies can optimize their resources in new construction and renovation projects, saving themselves—and U.S. taxpayers—millions of dollars. By making use of an agency’s guidelines and policies, the advocacy and resources of other Federal agencies (such as FEMP), and a project champion (often, the construction project manager) to keep it all on track, more Federal building projects can benefit from integrated, low-energy, sustainable design practices.

Design Guidelines

> When one has finished a building, one suddenly realizes that in the process one has learned something that one really needed to know in the worst way—before one began.
> *Friedrich Nietzsche, 1844-1900*

Executive Order 13123 directs Federal agencies to develop and utilize sustainable design principles. An agency's sustainable design guidelines are especially important in contracting for A/E services because language promoting sustainable design can be leveraged across all agency projects. Often, individual agencies—and individual organizations within agencies—have established such guidelines. Sustainable design guidelines are sometimes given their own section in project specifications. This has both advantages and disadvantages. One advantage is that an agency's sustainability considerations can be included in specifications rapidly by inserting a separate section. The primary disadvantage is that all members of the project design team will have to refer to and interpret the sustainable design section in regard to their own sections. For example, a person specifying plumbing vent pipe would be expected to read the sustainability section and consider recycled content, even though that requirement does not appear in the plumbing section.

To address this problem, some agencies (for example, the Bureau of Prisons) have identified all areas in their specifications where sustainability requirements should be added. And some private publishers have issued detailed guides to preparing specifications using "green" building products (see, for example, www.buildinggreen.com/news/greenspec.cfm).

The Department of Defense (DoD) and the military services have established the Unified Facilities Criteria (UFC) program to unify technical criteria and standards (see www.ccb.org/ufgs/ufgs.htm). The UFC provides a single criteria-publishing system with a uniform format for all agencies. The goal is to reduce duplication of information and provide unified documents, limiting agency-specific documents except when required by unique circumstances. In its early form, however, it consists mostly of documents applicable to a single military service. These offices administer the UFC program for the military services:

- Headquarters, U.S. Army Corps of Engineers (www.hq.usace.army.mil/hqhome/)
- Naval Facilities Engineering Command, Engineering Innovation and Criteria Office
- Headquarters, Air Force Civil Engineer Support Agency (www.afcesa.af.mil/).

Many agencies have adopted the Construction Criteria Base (CCB) information system as the distribution method for facilities criteria (see http://www.ccb.org/). These agencies include DoD, especially the U.S. Air Force and Army Corps of Engineers; DOE; the Department of Housing and Urban Development; the Veterans Administration; the Environmental Protection Agency; the Federal Emergency Management Agency; the Federal Highway Administration; the General Services Administration (GSA); NASA; the National Institutes of Health; the

National Institute of Occupational Safety and Health; the National Institute of Standards and Technology; and the Occupational Safety and Health Administration.

The CCB is connected to the *Whole Building Design Guide* (see www.wbdg.org), which provides one-stop shopping for design guidance, Federal mandates (Executive Orders and Federal Regulations), technical information, project management tools, and links to CCB data and other codes and standards. The *Whole Building Design Guide* is maintained by the National Institute of Building Sciences (www.nibs.org/) through funding from the NAVFAC Engineering Innovation and Criteria Office, the GSA, and DOE (including FEMP), with assistance from the Sustainable Buildings Industry Council (SBIC).

Many Federal agencies, such as the GSA and DoD, include language in their contracts that encourages the use of sustainable design in all new construction and major renovations, wherever technically and economically feasible. Tasks and tools are constantly evolving, however, so this language must be frequently updated to provide useful direction to contractors and other design professionals. Therefore, it is necessary to first review existing agency documents and determine how their directives can be used to encourage sustainable design. For example, the GSA prospectus development study (PDS) process allows energy and passive solar performance to be prominently called out as a fundamental design criterion, or "functional objective," in the Building Systems Matrix that summarizes project goals. GSA procedures for design and construction projects are outlined in "Public Buildings, Design and Construction*: How to Get Work as an Architect, Engineer, or Contractor with PBS* and *Public Buildings: Design & Construction Delivery Process*, both at www.gsa.gov (you can search for them by title).

It is important to note that no single design process is "sustainable" while others are "not sustainable." Rather, continuous improvement in all processes will result in better and better buildings. Rather than simply replicating "what worked last time," it is important to continually evaluate new products and methods. Design team members must also have a common understanding of what constitutes an improvement, so defining metrics is an important task for the team.

Establishing Selection Criteria

> Never contract with a man that is not better than thyself.
> *Confucius*

Selecting capable, experienced, enthusiastic individuals to be on the design team could be the most important step in the sustainable design process. Some A/E firms have a strong commitment to sustainability and view it as a leading design consideration. Others, however, while acknowledging that sustainability is desirable, do not see sustainability as central to determining the design and form of a building. To achieve a successful partnership between your agency and your selected A/E team, you must first clarify your agency's values and priorities and then hire a firm whose values are closely aligned.

As a first step, your agency will select a project manager and other key members of the team to oversee the project. It is recommended that the team include an advocate for achieving sustainable design features in the building. This team defines the selection criteria that will appear in the Request For Proposal for the A/E. Members of the team will have different interests and values regarding what criteria are most important for selecting the A/E. The team would discuss and agree on how much emphasis they want to place on sustainability in the selection process --how does it rank relative to other important design considerations? The selection criteria is a reflection of the priorities and values of an organization and the priorities determine how the funds are actually spent so it is important to have some internal consistency before you develop selection criteria and a scope of work. Once you develop a set of criteria (generally in the range of 4-8 topical areas), the next step is to assign a weight to each criteria. The weighting establishes the relative importance of the criteria. It is a way to achieve a consensus in terms of a set of criteria for selecting the A/E.

Here is an example of the selection criteria used by one agency to hire an A/E to design a new Federal laboratory building:

- Safety: Does the offeror clearly demonstrate their ability to design laboratories that incorporate Uniform Building Code H-6 requirements while meeting end-user functional requirements? (Weight 25 points)
- Technical Requirements: Does the offeror clearly demonstrate their ability to design to technical requirements? (Weight 25 points)
- Budget: Evaluate the firms ability on past projects to design to budget. (Weight 12.5 points)
- Budget: Evaluate the proposed cost of design services. (Weight 12.5 points)
- Green Buildings Technology: Does the offeror clearly demonstrate their capability to incorporate green buildings technologies as defined by the US Green Buildings Council Leadership in Energy and Environmental Design™? (Weight 12.5 points)
- Architectural Image: Does the offeror's proposal demonstrate capability in developing an architectural image consistent with the project site and owner's image? (Weight 12.5 points)

How do you select the right firm? First, the A/E firms you are considering should respond enthusiastically to inquiries about energy and resource efficiency. In their formal written and verbal presentations, they should address challenges and opportunities specific to sustainable design. The principal-in-charge and the project architect should demonstrate a familiarity with energy-efficient building design, material selection, and other key elements. And they should clearly describe a design process in which the energy implications of design decisions will be evaluated at each phase of the process with appropriate tools.

The design team must have demonstrable expertise and experience with design strategies and techniques for incorporating energy efficiency and sustainable design practices that meet life-cycle economic criteria. This expertise can be demonstrated by previously documented projects and by partnering with recognized energy and sustainable design experts. The consideration for energy efficiency and environmental quality should begin at the earliest stages of planning and follow through construction and operation. Also, there should be scheduled review of the energy and environmental startegies throughout the design process.

To maximize energy performance, the A/E team should be supportive and knowledgeable. An architect unconcerned with energy performance, even coupled with an engineering firm with impeccable energy credentials, is unlikely to produce an optimal building design. The reverse situation is also true. It is vital to select a team that is prepared to work together to achieve superior building performance.

Team Building

Too often in practice, an architect hands a completed architectural design to a mechanical engineer and says, “Make this work.” The mechanical engineer then sizes a mechanical system to meet the building’s peak load. By that time, decisions regarding building orientation, massing, and fenestration—which all affect energy use—have already been made. This late in the process, there is little or no opportunity to optimize the building as a whole system. The mechanical engineer can optimize only the heating, ventilating, and air-conditioning (HVAC) subsystem—which is usually the assigned task.

In fact, the mechanical engineer should have been analyzing mechanical system options as the architectural design was developing, to inform the architect about the energy use and cost implications of design decisions. Similarly, in order to have proper daylighting, the lighting designer should be consulted when the building plan is being laid out on the site.

Everyone involved in a building project might want to coordinate closely at the outset. But because of the way competitive design fees are conventionally structured and procured, there is no financial incentive to participate in meetings and correspondence, evaluate alternatives, and reach a consensus—which are essential to achieving a successfully integrated, sustainable design.

Sustainable design requires an integrated process in which the members of a project design team, who are usually from different disciplines, cooperate to exploit the interactions between building elements or systems. Teamwork involves collaboration and cooperation, as well as making a shared goal a priority. Team members work together better if they are all involved in setting project goals early in the process. Deliberate, planned efforts to communicate at each step help to ensure success.

Several trends promise to enable better design integration, including a growing emphasis on coordination and the use of new communication tools. Agency project managers realize that time spent on coordination early in the design process is likely to be returned several times over in terms of lower construction and operating costs, so they budget and schedule ample time for coordination meetings.

Information Sharing

Several powerful new communication technologies are making this coordination easier and less costly. They enable design team members in different locations to share information, analyze data, and generate results efficiently. Many design and construction professionals make use of "collaborative Internet sites" to share drawings and coordinate schedules. And efforts are under way in industry and in the national laboratories to integrate computer-aided design (CAD) drawings, energy analysis computer programs, cost-estimating procedures, and all processes in which information is shared. Of course, security is of prime importance, and some agencies use private networks such as the project extranet system developed by the GSA for multi-billion-dollar capital construction programs in the Washington, DC, area. Experience with these new tools, or a willingness to try them, can be part of the selection criteria for your A/E firm.

Project Manager Checklist: Selecting Design Professionals

You can use the following criteria to enhance sustainability in your solicitations for design services.

To be successful, applicants should—

- State their commitment to sustainable design in their cover letter or introduction to their proposal.
- Demonstrate their ability to respond to sustainability goals and targets set in program documents.
- Propose a team organization that can respond with a combination of communication channels and decision-making authority to the results of energy analysis and sustainability evaluations, such as a Leadership in Energy and Environmental Design (LEED) rating; successful teams should work together on a cross-disciplinary basis.
- Demonstrate familiarity with sustainability principles and sustainability rating criteria (such as LEED).
- Include a sustainability expert (such as a LEED Certified Professional) in a position of decision-making authority on the design team, or demonstrate familiarity with the applicable rating system and its design implications.
- Describe actual experience achieving LEED ratings for completed building projects.
- Demonstrate experience in planning, facilitating, and reporting on design charrettes.
- Demonstrate proficiency with employing, and using the results of, analysis tools (such as *EnergyPlus, DOE-2*, and *Energy-10*).
- Be able to cite completed projects that feature workable, cost-effective, energy-efficient, and low-energy design principles.
- Demonstrate an awareness of, and sensitivity to, the specific requirements of an agency or project, such as heightened security at a prison or foreign embassy.
- Demonstrate an understanding of the most recent Federal code, 10 CFR 434/435 (Code of Federal Regulations), or comparable commercial code, American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Standard 90.1.
- Demonstrate expertise and experience in cost-benefit analysis of energy-efficient design strategies for all major systems and components: HVAC, building envelope, orientation, thermal mass, shading, daylighting analysis and simulation; electrical lighting design, control and integration with daylighting; energy-management control systems; commissioning of energy systems; indoor air quality; efficient operation and maintenance of energy systems; and documentation of design intent for energy system performance.
- Demonstrate familiarity with emerging energy technologies such as high-performance glazings; waste energy recovery; new thermal comfort standards (and associated temperature and humidity monitoring requirements); non-CFC refrigeration options; ENERGY STAR® compliant equipment; HVAC under-floor systems; and HVAC controls to improve personal control.

- Demonstrate an understanding of renewable energy technologies, such as solar water heating and photovoltaics, and past experience with them.
- Demonstrate an understanding of site design to provide or restore habitat and promote biodiversity, and past experience with this.
- Demonstrate an awareness of new measurement technology and past experience with metering and monitoring of energy and water utilities.
- Demonstrate an awareness of the issues involved in operable windows and natural ventilation, and past experience with them.
- Demonstrate familiarity with techniques to minimize and recycle construction waste, and past use of them.
- Demonstrate a method to identify and use materials with recycled content, or materials from rapidly renewable resources, such as certified wood products; demonstrate an awareness of the use of salvaged or refurbished materials rather than new ones.
- Demonstrate knowledge of the generation and distribution of indoor air pollutants such as volatile organic compounds (VOCs), and demonstrate past measures taken to minimize emissions from building materials and control passage of pollutants between rooms; demonstrate familiarity with air quality monitoring technology.
- Demonstrate an awareness of designing systems for the collection of recyclable materials, and past experience with this.
- Demonstrate knowledge of the availability and use of locally manufactured products.
- Demonstrate knowledge and use of water-conserving fixtures and appliances; demonstrate awareness and past use of wastewater recovery systems and rainwater collection systems.
- Demonstrate an understanding of indigenous landscaping and strategies to use less water, fewer chemicals, and less labor for maintenance.
- Demonstrate an understanding of specifying and implementing enhanced "whole-building" commissioning and quality assurance processes, and past experience with them.
- Demonstrate competence with the life-cycle cost (LCC) procedures and criteria of 10 CFR 436 and current economic parameters (discount rate, inflation rate) specified for Federal projects.

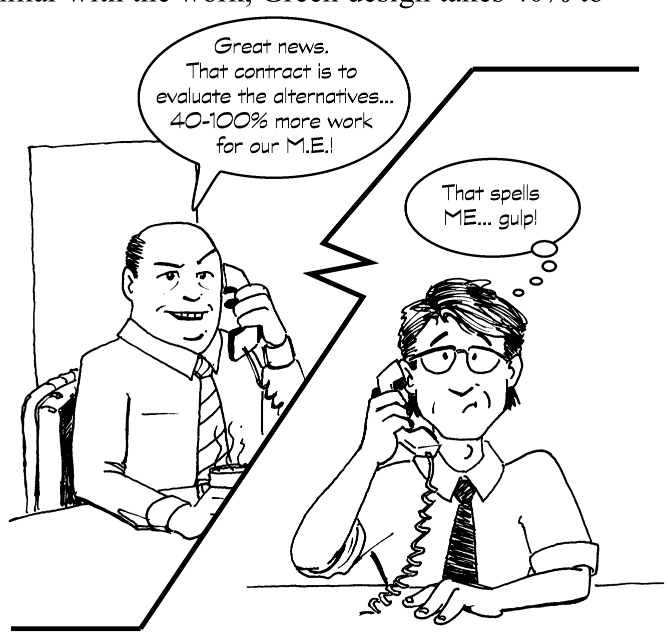
Preparing the Statement of Work

A statement of work that includes all tasks to be performed is essential in the procurement of an A/E contractor for an energy-efficient, sustainable Federal construction project. Schematic design, design development, construction documents, bidding and negotiating with contractors, and construction contract administration are considered to be an architect's basic services and are specified in the statement of work. A more comprehensive suite of services will also include predesign planning, such as project identification and analysis, feasibility studies, programming, land-use studies, and analysis of financing options. Other services can include attending or facilitating meetings to set goals and monitor progress, managing the construction, performing an energy analysis, conducting surveys of the sustainability attributes of various materials, and other consulting services. Special language is included in order to enhance consideration of sustainability in each of these phases, with emphasis on early phases of design when key decisions are made.

To continuously improve sustainability, the design team must research new technologies and be able to rank many alternatives, as well as employ sophisticated methods of evaluating performance. These tasks should also be included in the statement of work to ensure that they are completed and that the designer has budgeted enough hours for analysis and design team meetings.

Performance goals from the building program should be written into the statement of work for all subsequent A/E services. This establishes the contractual obligation to create a sustainable project. It also ensures a mutual understanding between the parties of what that means in terms of specific tasks. The statement of work should also specify the involvement of the mechanical and lighting designer as early as possible in the design process.

According to one mechanical engineer familiar with the work, Green design takes 40% to 100% more effort on the part of a mechanical engineer or an energy analyst than simply sizing the mechanical system. The mechanical engineer can use a "shoebox" model analysis (see *Setting Goals* in the Building Program section) to investigate various mechanical system strategies very early in the design. Then, the engineer continues the energy analysis as the design evolves, to keep the team informed about the energy-use and cost implications of design decisions.



The design project schedule must include time to conduct regular meetings of the project designers to communicate energy-use and cost implications and recommend alternatives. Time for investigating utility rates and programs should also be included and the results of utility rate investigation should be incorporated into the energy computer simulation in order to estimate annual energy cost of alternatives. The statement of work for the energy analyst should include assistance with compiling the building commissioning handbook, including the design basis and performance criteria.

For the energy analysis, a whole-building approach is needed to account for the interactions between systems. Exploiting these interactions is a key strategy in green building design. For example, energy-efficient lighting reduces the heat gain from lights, which allows a smaller chiller and significantly less energy for cooling to be specified. However, multiple measures must be considered in light of the fact that "you cannot save the same kilowatt-hour (kWh) twice." For example, a daylight sensor, which turns off electric lights in a room when sufficient daylight comes in through the windows, won't save any more energy or money if an occupancy sensor has already turned the lights off because nobody is in the room.

Most of these interactions are well-represented by hourly simulation computer programs such as EnergyPlus, DOE-2, *ENERGY-10*, and BLAST. These programs are based on first principles (laws of physics) rather than correlation, enabling them to evaluate an infinite variety of design configurations. The hourly simulation consists of an equation balancing the energy in and out of each building component, and these equations are solved simultaneously for each of the 8,760 hours of a typical year. Solving the system of equations at each hour accounts for the interactions between building envelope, heating, cooling, and lighting systems as well as solar heat gain, heat gain from occupants in the space, and other energy flows specified by the user.

There are four basic stages in building design:

- Predesign and preliminary design
- Schematic design
- Design development
- Design completion.

During predesign, the energy analyst develops the code-compliant reference case, identifies and evaluates energy efficiency and renewable energy strategies, and sets performance goals based on a case in which all effective strategies are implemented. During preliminary design, the task is to evaluate schemes and the sensitivity of results to variable inputs, such as utility rates, and then select strategies for further development. Schematic design will determine rough sizes of components. During design development, the analyst assists with determining precise sizes and complete descriptions of the designs. The analyst has the most input before the design is 35% complete. By the time it is 90% complete, the role of the analyst has been reduced to confirming that performance goals have been met.

The statement of work describing these services must include additional work needed to arrive at a sustainable design. The statement of work will include all the tasks required of the A/E firm, and would include the following sustainability requirements:

- More specific research into the client's needs and the most effective ways to meet them
- Detailed energy modeling
- Life-cycle-cost analysis
- Evaluation of alternative systems and materials
- Research and specification of energy efficient (EnergyStar) equipment and materials which satisfy various rating criteria or certification for health or sustainability.
- Development of documentation relating to sustainability rating criteria.

The statement of work for A/E services would address sustainability topics in each of the following: the building program, the schematic design, documentation, design development, value engineering, construction documents, assistance with bid solicitation and contract award, assistance during construction, commissioning, and measurement and verification. Each of these elements is described in greater detail below.

The Building Program

The building program is a document conveying the conditions and requirements for a project, including the owners project requirements and performance criteria. The program specifies the number of square feet of different types of space (office, assembly, laboratory, etc.) and the relationships between those spaces. The program should also state clear, quantitative sustainability performance goals. For example, it might specify the desired LEED rating (see *Setting Goals*) or a maximum annual operating cost in dollars per square foot.

Other goals often include achieving a facility that is beautiful, safe, reliable, and comfortable, or one in which the quality of air and light is superior. For some facilities, such as prisons, security might be central to the building program. The program may also put limits on the materials to be considered by dictating the intended "look and feel" of the building.

The agency's architectural guidelines regarding sustainability are referred to in the building program. The building program also documents the energy-related needs of users, a critical first step in designing systems to meet those needs efficiently, as well as an indicator of the suitability of various renewable energy sources.

The healthier environment and lower operating cost of a green building are key features in a prospectus and can enhance the feasibility of a project by increasing demand for more desirable space. Some agencies have discovered that potential partners (funding sources, local community stakeholders) are more enthusiastic about supporting a project with superlative goals than those resulting in a business-as-usual building. The building program contains the project's overall goals, specific goals for resource use and costs, and specific system performance targets.

Setting Goals

When the goals for sustainability can be clearly and quantitatively stated at the beginning of design and construction, they are more likely to be factored into all the decisions made throughout the process. Sustainability goals require definition and clear criteria that can be used to determine whether we have succeeded in meeting them. Goal setting can be done by the agency before the solicitation is issued, or by the entire design team after the A/E firm is on board.

> The cat only grinned when it saw Alice...
> 'Cheshire-Puss,' she began...
> 'Would you tell me, please, which way I ought to go from here?'
> 'That depends a good deal on where you want to get to,' said the Cat.
> 'I don't much care where…' said Alice.
> 'Then it doesn't matter which way you go,' said the Cat.
> '…so long as I get somewhere,' Alice added as an explanation.
> 'Oh, you're sure to do that,' said the Cat.
> *Lewis Carroll,* Alice in Wonderland*, 1865*

A good general goal for most Federal projects is to produce "a beautiful, sustainable, cost-effective building that meets its program, encourages productivity, and consumes as few nonrenewable resources as possible through the use of passive solar design, energy efficiency, and the use of renewable resources." However, unless quantitative aspects are included and can be measured later, it will be difficult to determine whether the goal was met. Sustainability rating criteria are one effective means of doing this.

Executive Order 13123 urges Federal agencies to increase the use of EnergyStar building tools. Energy Star buildings are those that demonstrate energy performance among the top 25% nationwide. The program has introduced tools to help develop and implement a plan including tools to set goals and assess performance. Energy Star is a rating that is maintained over time, rather than just initial construction. For more information see http://www.eere.energy.gov/femp/techassist/energy_star_bldgs.html.

The most popular sustainability rating criteria is the Leadership in Energy and Environmental Design, or LEED, system promulgated by the U.S. Green Building Council. LEED tallies points for prescriptive criteria and designates levels of performance: Certified, Silver, Gold or Platinum). For example, the building program might set the goal of a Silver LEED rating, which would have implications for water and wastewater, site selection, energy use and materials selection. Other sustainability criteria include the Building Research Establishment Environmental Assessment Method (BREEAM)/New Offices; Building Environmental Performance Assessment Criteria (BEPAC); and International Standards Organization (ISO) 14000, ISO 14001, Environmental Management Standard.

ASTM International's Subcommittee E6.71 has compiled more than 100 standards that address sustainability in buildings, including E1991, Guide for Environmental Life Cycle Assessment of Building Materials/Products; E2114, Terminology for Sustainability Relative to the Performance of Buildings; E2129, Practice for Data Collection for Sustainability Assessment of Building Products; and E917, Practice for Measuring Life-Cycle Costs of Buildings and Building Systems.

Ideally, goal setting is a team activity. Team members are more likely to proceed with a keen awareness of, and commitment to, project goals if they have some control in shared goal setting and determining metrics. Sometimes goal setting occurs before all design team members are on board, however. In such cases, general goals can be set and then made more specific with new team members, or a meeting can be held with new members to discuss and reaffirm previously set goals.

Energy performance goals can have different objectives. Annual energy use per gross square foot (Btu/ft^2/year) is a common metric in Federal projects because that is how progress is tracked toward the goals in the Energy Policy Act (EPAct) of 1992 and 1998 amendments, as well as those in Executive Order 13123. The shortcoming of using Btu/ft^2/year as a metric is that energy in Btu supplied by different fuels has different costs, and there is no differentiation between time-of-use or demand rates.

Another option is to specify an energy-use goal as a certain percentage less than that required by code, without sacrificing any performance in the comfort, habitability and health of the occupants. For example, a goal might be to use 25% less energy than that allowed by 10 CFR 434/435 for Federal projects, by ASHRAE 90.1 for commercial buildings, or by California Title 24 for buildings in that state. A very useful metric is annual operating cost, which accounts for the cost of different fuels as well as various time-of-use and demand savings. Annual operating cost also integrates well as a figure of merit with all other annual costs, such as operation, maintenance, water, and disposal.

It is important to use the same yardstick to measure performance as the one used to set the goal in the first place. Goals set using a computer model are often hard to compare to actual utility bills, because of variables outside the designer's control that affect energy use after a building is occupied. Although the performance of the building will ultimately be determined by the actual use of resources (such as utility bills), the performance of the design team should be evaluated by simulating the final design with the same computer program and uncontrolled parameters (weather data, utility rates, occupancy, schedules, plug loads) that were used to set the goal.

How do you set an energy goal before you know what the building looks like? One approach is to model a default building in the shape of a shoebox with the same floor area and number of floors, the same occupancy schedules, and the same kinds of space (office, circulation, kitchen, meeting rooms, storage, etc.) called for in the building program. A shoebox shape, with a length about twice its width, is selected because a cube shape would minimize surface area and would thus be an extreme selection for the base case.

First, a base case is defined to serve as a benchmark with which to compare the performance of the evolving design. For the base case shoebox model, the properties of walls, roofs, windows, and mechanical systems are the minimum required by applicable codes. The annual energy performance of the base case shoebox model is evaluated using climate data and utility rates for the site.

Second, a suite of energy-efficiency measures is modeled using the shoebox to determine which strategies are most effective. For example, if evaporative cooling is effective for the shoebox model, it is likely to be effective for the actual design. Measures are evaluated in combination with each other to account for interactions.

The shoebox model with the most cost-effective package of measures provides an estimate of what should be achievable in the design, but the goal is usually set above this level. For example, a reference case might be 100 Btu/ft^2/year, the shoebox with all cost-effective measures implemented might be 30 Btu/ft^2/year, and the goal for the project might be set at 40 Btu/ft^2/year. The *ENERGY-10* computer program has been developed to implement this predesign analysis and to assist design teams in setting energy-use goals.

Establishing the Base Case

Establishing an appropriate base case building is the first step in evaluating low-energy design and other sustainability investments during the design process. Goals for resource use and cost are set relative to the base case. Establishing a viable base case is also an essential step in pursuing a performance compliance path under 10 CFR 434/435 or the comparable commercial code, ASHRAE 90.1.

This task can be deceptively difficult, because there is no universal approach. Early in the programming phase, the base case may be the minimum, code-complying structure in a generic shoebox form. But some codes or rating systems (e.g., ASHRAE 90.1 and LEED) specify that the base case building shape must be the same as the evaluated design. The problem with this requirement is that it does not reward the architect for innovations in building aspect ratio or orientation that improve energy use or reduce materials and costs. For example, designers of the Zion National Park Visitor Center achieved considerable savings by moving some program space (educational display boards) outside the building envelope.

It is thus desirable for the base case to be defined to help identify related savings and reward the design team for improvements. It is often necessary, however, to define a base case building during the programming phase, to establish aggressive energy performance or material-use targets. If this is the case, you will probably want to retain the same base case definition throughout the project.

Decisions made regarding the definition of the base case will have implications in decisions about cost-effective interventions in the final design. Consequently, establishing the specifications of an appropriate base case building design is important, and the project manager and design professional or energy consultant should accomplish this early in the design process.

Defining Performance Targets

After choosing sustainability rating criteria that will be a yardstick for measuring performance, we then need to specify what level of performance (what tick mark on the yardstick) we aspire to. An energy performance target is a subset of the general sustainability target—a quantitative goal or measure of the maximum expected energy consumption for a structure, based on accepted calculation procedures.

In smaller projects (projects of approximately 10,000 ft^2 or less with only one or two thermal zones, such as warehouses, small offices, or individual residences), it can be helpful to use quick, design-based, climate- and program-specific energy software such as *ENERGY-10*, Building Design Advisor, or Energy Scheming during programming. Using these software packages, Federal managers or their subcontractors can incorporate numerical energy targets, including breakdowns of estimated energy consumption for heating, cooling, ventilation, plug loads and lighting, into their program documents. Incorporating this kind of information in a program statement provides criteria against which to evaluate subsequent design performance.

For larger, multizone projects such as laboratories and high-rise office buildings, it is necessary to run more complex software packages, such as EnergyPlus, DOE-2.2, BLAST, or the equivalent to generate similar estimates of energy consumption. These tools estimate annual energy consumption accounting for a wide range of factors, including building size, local climate, mechanical system control strategies, utility rates, maintenance practices, and occupancy schedules. Energy modeling can be time-consuming and expensive, as detailed below. An alternative is to use national average energy consumption data by building type (available through the Energy Information Administration in DOE) as a reference and cite a target as a percentage reduction from the data. For example, in the year 2000 Federal building energy cost averaged \$1.11/ft^2/year, which provides a useful point of reference.

In designing new office space, it is economically realistic to reduce energy costs from 30% to 50% below national averages by applying an optimum mix of low-energy design strategies to the building design. These strategies might include optimized glazing and insulation, daylighting, shading, and passive solar heating. Even greater savings are feasible when advanced technologies and techniques are employed. This suggests that an annual savings of between \$0.45 and \$0.75/ft^2 of office building is a reasonable estimate of the maximum cost savings possible using energy-efficient design. However, if you compare energy consumption in your new design to a hypothetical base case building rather than to the national mean for existing structures, the savings could be more modest. In this instance, savings might be expected to range from \$0.20 to \$0.30/ft^2/year, depending highly on the definition of the base case building.

These numerical goals are often established as targets rather than absolute project criteria. The great variety of building types, programs, and conditions makes it challenging to set goals which do not involve some uncertainty and are not difficult to enforce. Nevertheless, incorporating target goals into a programming document conveys the seriousness of energy consumption as a design issue. By asking potential design contractors to comment on this information in their proposal submissions, you can more readily evaluate their energy responsiveness and insights.

Project Manager Checklist: Programming

- List sustainability as a core value along with the other requirements in the program.
- Stress the goal of employing sustainable design alternative whenever economically and technically feasible in program documents.
- Highlight achieving superior whole-building performance as a written project goal, and select criteria to evaluate performance.
- Establish a base case established in the program, based on a shoebox-shaped building with the required square footage, climate, and code-compliant assumptions.
- Conduct a project-programming workshop with key agency personnel.
- Establish base case defined by minimum code requirements. Base case is often a building in the shape of a shoebox with the same square-footage as the building program.
- Establish quantitative energy targets in the program based on a suite of measures that are suitable for the base case shoebox (percent reduction in energy use from the requirements of ASHRAE 90.1).
- Specify which energy analysis software will be acceptable (DOE-2, *ENERGY-10*, or equivalent).
- Indicate a target LEED rating in the building program:
  - LEED Certified, 26-32 points
  - LEED Silver Level, 33-38 points
  - LEED Gold Level, 39-51 points
  - LEED Platinum Level, 52+ points
- Include considerations for storm-water runoff, on-site infiltration, or on-site treatment to limit disruption to natural water flows on site.
- Include considerations for minimizing building and parking footprint and moving appropriate program spaces outdoors; consider redevelopment of developed areas instead of Greenfield development.
- Include language in the program mandating the use of renewable energy or cogeneration applications determined to be cost-effective.
- Establish aggressive targets for lighting power density (W/ft^2); consider power densities 20% below standard practice where feasible.
- Include waste recovery and provisions for recycling (separation, collection, storage) in the building program.
- In the building program, require a waste management plan to divert demolition, construction, and land-clearing debris from the landfill through recycling or salvage.
- Require recycled or recyclable, rapidly renewable, locally available materials in material selection criteria.
- Ask for the use of native or drought-tolerant plants in the landscaping described in the building program.
- Establish indoor air quality requirements (ASHRAE 62), requirements for indoor pollution sources, and the location of outdoor air intakes.

- Include in the building program any requirements of access to daylight or lines of sight to vision glazing (percent of space). Note any types of space in the program that would be enhanced by direct penetration of daylight, as well as any spaces that could not tolerate such direct penetration.
- Include permanent entryway systems to capture particulate matter.
- Establish comfort criteria in the building program (ASHRAE 55). Include humidity, radiant heat gain, and temperature as determinants of human comfort.
- Establish in the building program the intention to continuously monitor building energy performance, indoor air quality, and comfort conditions.
- Indicate in the building program the need to evaluate access floor systems for mechanical, electrical, and communications distribution equipment.

The Schematic Design

> We shape our buildings; thereafter they shape us.
> *Sir Winston Churchill, 1874-1966*

The statement-of-work must describe all schematic design studies, showing the scale and relationship of project components. Submittals include drawings, specifications, and a cost estimate. This package provides the owner with a description of the design for review and approval and addresses project requirements and costs. Clearly, any suitable sustainability measure must be included in the schematic design, because in subsequent phases, these concepts are further developed but new ones are rarely added.

Sometimes an agency will require a design team to develop several schematic design alternatives. The work required to compare them—such as energy modeling for all options in order to compare energy use—must be accommodated in the statement of work and cost estimate of a project. This could stipulate that each alternative be scored according to sustainability rating criteria (e.g., a LEED score for each).

Require as part of the RFP a sustainable design report that explains how the design accomplishes the desired green goals. A paragraph in the RFP would require that the report contents include impact of building siting and footprint and discussion of the form and orientation of major spaces as it relates to sustainable design, energy modeling showing how the schematic design adheres to energy goals, and efficiency parameters for mechanical and lighting systems.

Regarding energy, the schematic design submittal required in the RFP should include the size of major energy system components and how strategies interact. In addition to floor plans, elevations, and type and size of mechanical system components, you can require that the following information be submitted:

- *The Building Plan:* Dimensions and a layout accommodating green building design strategies. For example, a double-loaded corridor is often suitable for daylighting and natural ventilation. The design team would describe any strategies that affect the shape of the building, such as open or private offices, perimeter circulation spaces, orientation, earth-protection, an articulated or compact plan, atria, and sunspaces.
- *Daylighting:* Size, number, and position of apertures (windows, roof monitors), relative dimensions of shading overhangs and light shelves, type of control (switching or dimming), number and location of light sensors, and requirements for room surface finishes (colors) and window glazing (visible transmittance and solar heat gain coefficient).
- *Passive Solar Heating:* Window areas and glazing properties (solar heat gain coefficient, U-value), amount of thermal storage material and relative position of glazing and mass, optimal levels of envelope insulation (R-values), size and relative position of shading and overheat protection.
- *Natural Ventilation:* Size and relative position of apertures (operable windows, vents), controls, and interface requirements for the HVAC system.

- *Solar Water Heating Systems:* Solar collector area, location and orientation; amount of thermal storage (water tank volume); system schematic with heat exchangers and pumps; control strategy.
- *Solar Photovoltaic System:* Area, location, orientation and rated capacity of PV array; capacity of energy storage batteries (if any), type and capacity of power conditioning equipment (inverter).
- *Solar Cooling Load Avoidance:* Size, location, orientation of window overhangs. Reflectivity of roof surface. Glazing properties: Solar Heat Gain Coefficient, visible transmittance.
- *Solar Ventilation Air Preheating:* Size, location, and color (black is best but other dark colors work) of the perforated metal siding; connection to distribution ductwork. Consider any security concerns regarding ventilation air intake.

For each energy savings measure, and for the optimal combination of measures, the schematic design should include estimates of its energy use and operating cost, along with an estimate of probable construction costs. This information influences decisions about what should be included in the schematic design based on life-cycle cost-effectiveness. Concepts included in the schematic design are carried over into design development.

The energy analysis includes an hourly simulation to evaluate different schematic designs and interactions between measures. Measures can be considered independently (single measure included), and elimination parametrics can also be used (single measure excluded) to evaluate the impact of a measure on the building as a whole system. The analyst can then rank strategies based on their performance and life-cycle cost. The objective is to select systems for design development. New strategies or technologies cannot be added to a fully developed design. Thus, it is important that all information needed for decision-making be obtained before the schematic design is completed (e.g., in a design charrette or from consultants).

Energy modeling with hourly computer simulation programs is essential for green design. But energy modeling is a specialized field, and the programs are very detailed. Someday, CAD software for creating designs will link directly to an energy analysis program. In the meantime, the tedious task of doing *takeoffs* (reading dimensions off plans and entering them into the energy program) falls on the mechanical engineer or energy consultant.

The energy analysis requires several iterations to analyze multiple design alternatives, including these:

- Building envelope and orientation
- Size and type of HVAC plant
- Type of distribution system
- Control set points
- Daylighting apertures and control
- Efficient lighting
- Renewable energy supplies.

Energy Analysis and Software

> Get the habit of analysis—analysis will in time enable synthesis to become your habit of mind.
> *Frank Lloyd Wright*

There are many kinds of analysis techniques. These include calculations (such as loads and energy consumption programs), physical and computer modeling (such as daylight study models or light-tracing simulations), and testing (such as infiltration or HVAC equipment efficiency studies). Individual projects can benefit from some or all of these studies.

The most common forms of analysis procedures involve calculations. Although hand-based methods remain valid and can be used, today most designers and consultants use computer-based methods. These software programs have varying levels of accuracy, are intended for different phases of the design, and require very different levels of effort and cost. As a Federal manager, your goal should be to match an appropriate level of analysis to the task at hand.

Computer simulations such as EnergyPlus, DOE-2.1E and BLAST require input detailing a developed design. Consequently, they are generally reserved for later in the design process, when many architectural decisions have already been finalized. Tools such as *ENERGY-10,* and *eQUEST*® have been designed using intelligent defaults to provide immediate feedback to the designer or project manager during the earliest phases of a project. Still other software packages—such as the proprietary program Trace—have been developed to assist in mechanical equipment selection and sizing and are often distributed by manufacturers. They are generally used only after all building envelope and massing decisions have been finalized.

Match the Tool to the Task. Calculations are made of building energy performance for two primary reasons: either to size mechanical equipment or to predict the annual energy consumption of a structure. Although these two tasks are not mutually exclusive, and some programs can handle both tasks, they tend to be conducted in isolation. Any energy analysis should determine both peak loads (sizing requirements) and annual energy consumption. The cost of an efficiency measure is partially offset by a reduction in the size of the mechanical system serving that load, so it is important to include equipment sizing in the economic calculation.

Sizing programs are primarily geared to calculating peak hourly load conditions independently during the heating season and during the cooling season to size mechanical equipment. Almost all buildings have a sizing analysis of some kind run by an architect, engineer, or mechanical contractor in order to select the equipment. Most sizing programs are based on consensus procedures and algorithms established by ASHRAE, but many are proprietary products distributed or sold by equipment manufacturers.

Annual consumption programs are designed primarily to analyze the total energy consumed by a structure in a typical year and expressed in terms of Btu, dollars, or pollution avoidance. The most accurate of these software packages calculate building loads on an hourly basis; they assume that the structure uses a mechanical system of some defined efficiency and a control strategy to meet this hourly load. Based on the inefficiencies of the mechanical system and the distribution system of the building (e.g., ductwork losses), the program can then estimate building energy consumption for that hour. Annual performance is calculated by summing hourly results for all 8,760 hours of the year. In many cases, annual energy consumption programs include provisions for inputting utility rate structures so that annual energy cost values (not only Btu consumption values) can be determined.

Who Should Perform the Analysis? Energy analyses can be performed in-house or out-of-house; they can be run by the primary design contractors (if they have adequate energy expertise) or by energy consultants. The most important thing to remember is that the results must be taken seriously and be given sufficient weight in the course of the design.

Project Manager Checklist: Determining Energy Analysis Techniques

- ❑ Match the design tool or software to the project phase.
- ❑ Establish a reasonable budget for project energy analysis and consulting services.
- ❑ Is there a reasonable correlation between potential energy savings and investment in energy analysis and consulting services?
- ❑ Have you ensured a process by which the information generated from quantitative energy analyses will have an impact on the design process?
- ❑ Specify the requirements of 10 CFR 436 (which specifies methods, discount rates, and fuel escalation rates) as the method by which the cost-effectiveness of energy investments is to be determined.
- ❑ Specify in the RFP that the output of the energy analysis will meet the requirements of the LEED documentation (otherwise the base cases could be different and may necessitate separate runs for LEED documentation)

*Energy Analysis Software***.** Descriptions of energy analysis software can be found at www.eere.energy.gov/buildings/energy_tools. Some programs are proven to be effective for goal-setting and design evaluation. They include the following:

BLAST
BLAST Support Office
1206 West Green Street
Urbana, IL 61801
(217) 333-3977

Building Design Advisor
Energy and Environment Division
Lawrence Berkeley Laboratory
University of California
Berkeley, CA 94720
(510) 486-4000

DOE-2
Building Energy Simulation Group
Energy and Environmental Division
Lawrence Berkeley Laboratory
University of California
Berkeley, CA 94720
(510) 486-4000

ENERGY-10
Passive Solar Industries Council
1511 K. Street, N.W., Suite 600
Washington, DC 20005
(202) 628-7400

EnergyPlus
www.eere.energy.gov/buildings/energyplus/

Energy Scheming
Energy Studies in Buildings
Laboratory Department of Architecture
University of Oregon
Eugene, OR 97403
(503) 346-3656

HAP (Hourly Analysis Program)
Carrier Corporation
P.O. Box 4808
Syracuse, NY 13221
(315) 432-7072

TRACE
The Trane Company
3600 Pammel Creek Road
La Crosse, WI 54601-7599

The Design Charrette

> An idea is salvation by imagination.
> *Frank Lloyd Wright*

A design charrette is an intense effort to complete a design in a short period of time. The scope of work should include time for all disciplines to participate in one charrette before or early in schematic design and perhaps one more near the end of the schematic design. Because a large number of professionals participating, charrettes can be costly events, perhaps as much as $40,000 for the participants' time, travel, and logistics expenses.

Charrettes often consist of plenary sessions and specific breakout sessions. The breakout sessions might address topics such as lighting, mechanical systems, material use, water and wastewater, site and landscape, and other specific areas of interest to charrette participants. During plenary sessions, participants expose and exploit interactions between topics discussed in the breakout sessions and bring the discussion back to a whole-building perspective. Charrette participants first listen, in order to understand the goals, needs, and limitations of a project. Then, they envision and discuss creative but realistic solutions.

The scope of work for the architect could include facilitating the charrette, or this responsibility could fall to the sustainability consultant. The scope of work should include a professional, dedicated recorder to record ideas as they are mentioned and express these ideas in a charrette report. Include in the Charrette scope of work an independent recorder to ensure that the record includes not only the views of the most vocal participants or of the facilitator, but every concept, no matter how softly presented. It might be desirable to recruit a recorder with artistic graphic skills to make the proceedings more engaging for the participants and to make the resulting report more colorful and interesting.

Since each aspect of the design affects all other aspects, it is best to involve a wide range of stakeholders in a charrette. In addition to the project's owner and representatives of all agencies, disciplines, and firms on the design team, a charrette could include those from electric, gas and water utilities; surrounding community associations; water quality and air quality management districts; industrial partners and technology experts; financial institutions; and environmental organizations.

Project Manager Checklist: Additions to the Statement of Work

The statement of work and budget must accommodate the additional work to evaluate alternatives and greater communication needed for effective teamwork and sustainable design. Integrating otherwise disparate activities requires more than communication, however. It also requires that sustainability goals established in early program documents be shared across the team, and that the tasks required to integrate them with the work of others be included in contractual documents. Additional work includes, but is not limited to, the following items:

- ***Architect***
  - ❑ Ascertain the owner's requirements regarding sustainability.
  - ❑ Lead the process of setting goals for the design team.
  - ❑ Evaluate progress toward sustainability goals and coordinate creation of a building design that meets the goals.
  - ❑ Integrate the work of all disciplines to achieve effective daylighting, and any other goals requiring interdisciplinary cooperation.
  - ❑ Administer the construction contract to ensure proper implementation and integration of sustainability measures.
  - ❑ Inspect and evaluate the reuse of any existing structures on site.
  - ❑ Investigate availability and then specify recycled, salvaged, or reused building materials.

- ***Landscape architect***
  - ❑ Evaluate and optimize measures to reduce water use in landscape.
  - ❑ Optimize efficiency of irrigation system.
  - ❑ Evaluate and optimize measures to reduce chemical use (insecticide, fertilizer) requirements.
  - ❑ Consider the landscape's impacts on building energy use by siting and planting to provide shade and wind breaks.
  - ❑ Provide for stockpiling of topsoil for reuse.
  - ❑ Participate in the development of an erosion control plan.
  - ❑ Minimize paved areas and preserve or restore native vegetation.
  - ❑ Participate in the design of rainwater catchment and greywater use systems.

- ***Structural engineer***
  - ❑ Integrate the need to withstand physical forces with sustainability design requirements, including the size and location of window openings, required clear spans, structural members that do not block distribution of daylight, and the storage of heat in structural mass.
  - ❑ In the selection of structural materials, consider recycled content, environmental impacts of extraction and delivery, and embodied energy.
  - ❑ Inspect and evaluate the reuse of any existing structures on site.

- ***Civil engineer***
  - ❑ Address issues of site sustainability, including surface water runoff.

- Prevent sedimentation of streams.
- Design structural control measures to retain sediment.
- Participate in the development of an erosion control plan.
- Design the treatment system to remove suspended solids and phosphorus from storm water.
- Work with landscape architect to evaluate options for detaining surface runoff with landscape features where the water is used to water landscape features.

- ***Mechanical engineer or energy analyst***
  - Establish a base case model for energy-use calculations.
  - Implement a suite of measures to optimize the goal set in the building program (minimize life-cycle cost or minimize energy use) in order to set a quantitative energy-use goal.
  - Frequently calculate the energy use of the evolving design alternatives and inform all the other team members of the life-cycle energy use implications of major design decisions and progress toward the stated goal.
  - Evaluate alternative system types and design an HVAC system that optimizes efficiency.
  - Right-size (rather than oversize) the system by more carefully ascertaining the requirements and taking measures to mitigate risk of discomfort.
  - Consider innovative methods such as displacement ventilation, solar, or geothermal heat to save energy and improve indoor environmental quality.
  - Evaluate the environmental impacts of materials (refrigerants) used in the mechanical system and consider them in selection.
  - Prepare or assist in the preparation of special drawings and specifications to describe energy features of the design.
  - Participate in the design of solar water heating system with the plumbing engineer.
  - Design instrumentation systems to monitor the long-term performance of major building systems (with the electrical engineer).
  - Design systems to contain and remove tobacco smoke from designated areas.
  - Design occupant-based control (e.g., CO_2 monitor) of mechanical systems.
  - Design individual personal control of temperature, humidity, and airflow.
  - Design mechanical system controls that respond to open windows (turn off).

- ***Electrical engineer***
  - Integrate the use of innovative sources of power, such as cogeneration or solar energy.
  - Optimize the efficiency of distribution system hardware (transformers).
  - Optimize the efficiency of any other specified electrical equipment.
  - Design instrumentation systems to monitor the long-term performance of major building systems, including temperature and humidity.

- ***Plumbing engineer***
  - Establish baseline water use and lead in setting water reduction goals.
  - Select fixture and pipe layouts to conserve material.

- Include recycled content and environmental impacts in material selection.
- Evaluate and specify low-flow fixtures.
- Optimize pumping power through pipe sizing for recirculation loops.
- Optimize warm-up time through pipe sizing for buildings without recirculation loops.
- Participate in the design of rainwater catchment and greywater use systems.
- Participate in the design of a solar water heating system.

- ***Interior designer***
  - Specify recycled and recyclable furniture, furnishings, and fixtures.
  - Specify colors (contrast) that allow lower lighting levels.
  - Select furniture upholstery options that are durable and comfortable over a wide range of temperatures.
  - Investigate the emission of volatile organic compounds from paints, composite products, and carpets and specify low-VOC alternatives.

- ***Lighting designer***
  - Minimize installed lighting capacity through architectural design of the lighting system.
  - Use a task-and-ambient lighting strategy.
  - Design a system to admit, distribute, and control daylight.
  - Design controls to integrate daylight and artificial light.
  - Include measures to increase personal control of lighting.
  - Design measures to control direct illumination leaving the site.

- ***Environmental building consultant*** *(e.g., a LEED-accredited professional)*
  - Make recommendations regarding the impact of building materials as they are produced and the waste they generate in the construction process and over their product life cycle.
  - Organize and facilitate coordination meetings or charrettes.
  - Maintain a record of progress toward stated sustainability goals (for example, maintain a LEED checklist).

- ***Indoor Air Quality Consultant***
  - Study room-to-room airflow and recommend measures to prevent contamination from spreading from pollution sources.

- ***Waste management consultant***
  - Recommend ways to minimize construction waste and maximize recycling of it.
  - Recommend ways to enhance recycling over the building's life.
  - Recommend ways to enhance on-site recycling (design and siting of collection stations).

- ***Contractor*** *(trades)*
  - Recruit early to review and ensure the constructability of the design.
  - Recommend innovative improvements regarding installation.

- ***Operation and maintenance (O&M) staff***
  - Advise the design team about the O&M implications of design options.
  - Participate in early meetings to understand and support the sustainability goals of a project.

- ***Commissioning agent (predesign to post-occupancy)***
  - Be involved from the predesign phase to add commissioning-related requirements.
  - Prepare commissioning-related requirements for construction documents.
  - Include commissioning in the design review.
  - Prepare recommissioning manual.
  - Review at the end of the warranty period.

- ***Owner*** (While not contracted for, owner's role is a key determinate of sustainability)
  - Declare sustainability as a requirement and functional objective in the preamble to the statement of work (reiterating requirements already established in the building program).
  - Avoid building on farmland, habitat of threatened or endangered species, flood plains, wetlands, or parkland.
  - Consider redevelopment of urban areas over greenfields.
  - Consider rehabilitation and development of brownfields.

Documentation

Documenting the decision-making process is important. It records how the design progressed and keeps the owner and new team members informed, thus avoiding the need to revisit decisions that have been made. The statement of work must include development of a Design Narrative (in addition to specifications and drawings) and documentation of the basis of the design. The dual needs of weighting criteria and documentation can be satisfied by setting up a bookkeeping system for priorities, numerical values of various weighting criteria, and a convenient format for reporting the rationale of design decisions.

The LEED rating criteria system provides a method to quantify green building design measures, and it may be useful as a system of weighting a team's criteria. The task of collecting and presenting documentation for a LEED rating should not be underestimated and should be accounted for explicitly in the statement of work. Documentation costs an average of about $20,000, depending on the complexity of the project and how effective the team is at sharing documents. Efforts are underway to simplify the documentation requirements.

Design Development

During design development, drawings and documents are prepared to describe the entire project in detail. Drawings and specifications describe the architectural, structural, mechanical, electrical, materials, and site plan of the project. In design development, the team arrives at sustainability strategies and systems based on the brainstorming and selections that took place in the schematic design phase of the project.

The energy analyst performs a more detailed analysis, including cost and performance trade-offs between alternative systems. The architect, mechanical engineer, and electrical engineer work together to place renewable energy sources (e.g., solar water heating, solar ventilation preheating, photovoltaics) in such a way that they do not look like afterthoughts or add-ons. Mechanical system options (e.g., thermal storage, economizer, night cooling, HVAC controls, evaporative cooling, ground-exchange) are specified at the component level. And the lighting system design development integrates daylighting, equipment, fixtures, and controls.

Communication during design development is key. A change in any system, such as lighting power, could affect all other systems, such as cooling load on the mechanical system. It is wise to conduct design reviews that are both internal and external to the project team. The focus of design review efforts should be on the early schematic design submittals. After the design is 35% complete, it is usually too late to make major changes. Reviews should focus on preliminary and schematic designs, and ensure that sustainability measures are included for subsequent development.

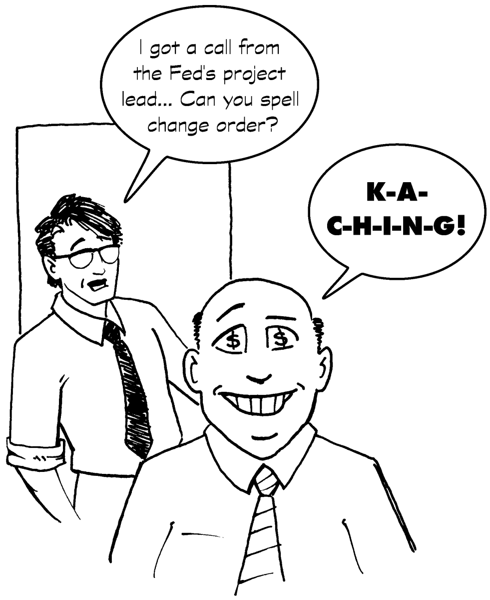
Objective parties who have not been involved in the design might be recruited to review it. These reviewers could include consultants, advocates from state and local governments or National Laboratories, and experts on sustainability topics such as energy, materials, and indoor environmental conditions. Reviewers usually point out strengths as well as weaknesses, and they try to be constructive with solutions to perceived problem areas. Many facilities have a design review panel, which meets periodically and provides an external review of design submittals.

To put the designer on the defensive would rupture the team approach and make sharing of information problematic in subsequent reviews. A reviewer might take a questioning approach in order to lead a designer to new thinking. Design reviews can be accomplished by marking up plans and specifications and by supplying product literature and other information to facilitate implementation of the recommendations. It is also useful to call a meeting to convey to the design team some of the more complicated concepts from reviewers.

Value Engineering

During value engineering, the design is scrutinized to determine how the same result or a better one can be achieved at a lower cost. Value engineering sometimes focuses on the functional mission of a building, but it is important that sustainability goals not be compromised as an important intent of the design. Value engineering should be based on life-cycle cost rather than first cost.

Energy analysis should be incorporated into the value engineering process in order to inform the value engineer of the consequences of deleting important energy features. The analysis can also help to ensure that energy targets and goals are maintained through the value engineering process. The energy analyst performs analysis and computer simulations as needed to determine the effects of proposed cost cuts and to defend justified measures.



The value engineering professional is not always the enemy of the sustainability advocate. In fact, sometimes this phase provides a final opportunity to include a sustainability measure that reduces first costs or has other compelling benefits.

Construction Documents

During this phase of the project, the design team prepares working drawings and specifications. These were generated during design development, approved by the owner, and confirmed as meeting the sustainability goals in the building program. At this point, it is too late to add new strategies or measures. So, sustainability and energy experts now only try to ensure that sustainability measures developed in the design phase are being carried out.

In this phase, the design team also prepares necessary bidding information, determines the form of the contract with the contractor, and specifies any special conditions of the contract. The construction documents contain all the information necessary for the bid solicitation, in other words, all the information that bidders need to accurately cost the labor and materials.

The team also ensures that architectural, mechanical, and lighting details and specifications, as well as commissioning specifications, meet energy goals. They then perform a final energy analysis to confirm that the energy goals will be met and to provide the documentation required for LEED certification or other purposes.

The project team must plan and budget for collecting documentation to evaluate environmental performance criteria and preparing green specifications. The green attributes of a specified material or method must be described, and information should be included to assist the installation subcontractors in adopting some new material or technique. Special sustainability measures can include specifications or materials that are nonstandard and difficult to estimate in terms of cost. In that case, a consultant might be asked to provide information about specific products or processes. Careful specifications are key to keeping costs down while promoting change among suppliers and subcontractors.

The result of this final design effort is a package of drawings and specifications to be included in construction contract documents. Forms certifying that the construction documents comply with all applicable codes and standards (including those related to energy and environmental requirements) are signed, and the plans are stamped by the architect and professional engineer. Contract documents are often organized according to the structure in Table 2.

Table 2. Elements of a Construction Contract

Bidding Requirements	Invitation Instructions Information Bid Form Bid Bond
Contract Forms	Agreement Performance Bond Payment Bond Certificates
Contract Conditions	General Supplementary
Specifications (in numbered divisions)	General Site Work Concrete Masonry Metals Wood and Plastics Thermal and Moisture Doors and Windows Finishes Specialties Equipment Furnishings Special Construction Conveying Systems Mechanical Electrical Sustainability (?)
Drawings	Site Architectural Electrical Mechanical

Source: C.M. Harris, Ed., *Dictionary of Architecture and Construction, 2nd Edition,* ISBN 0-07-026888-6, New York: McGraw-Hill, Inc., 1993.

Assistance with Bid Solicitation and Contract Award

During the bidding phase of a project, bidders submit offers to perform the work described in the construction documents at a specified cost. Offers include proposed costs for all construction described in the documents, as well as other direct construction costs. Bids do not include design team fees, the cost of the land, rights of way or easements, or other costs that are the responsibility of the owner or otherwise outside of the scope of the construction contract.

The statement of work for the design team should include supporting the owner in bid solicitation and negotiation. This way, the team has an opportunity to maintain sustainability goals if any costs have to be cut. The statement of work for the energy analyst should include studies to evaluate trade-offs or substitutions. Since the contractor is providing all the labor and materials to complete construction, bidders may want to substitute materials they are familiar with or have ready access to for those specified for their sustainability benefits. In such cases, a sustainability expert should remain involved to advise the owner and encourage a compromise that optimizes the benefits of the materials selected.

Assistance during Construction

Administration of the construction contract is often included in the architect's and design team's basic services. The scope of work should include specific monitoring of sustainability and energy-related aspects during construction**.** Many energy efficiency measures, such as insulation and vapor barriers, require special attention to details during installation. Special instructions from the design team will help to realize that the benefits of these measures.

It is often too late to correct problems if they are discovered by the commissioning authority after installation. For example, it is much more expensive to correct sagging or missing insulation after the drywall and interior finish are installed. Again, the design team maintains adherence to sustainability goals as change orders are issued and if cost-cutting is required. Additional analysis may also be required to evaluate cost and performance trade-offs.

Commissioning

Commissioning processes confirm that building systems are installed according to the intent of the design. Unlike testing and balancing, which are part of the construction contract, commissioning is often performed by a third party commissioning authority on behalf of the owner.

Beyond the scope of typical commissioning, commissioning that enhances sustainability entails the earlier involvement of the commissioning authority to develop a record of the design intent with respect to energy efficiency and sustainability. The commissioning authority's early design reviews and recommendations result in system designs that are not only easy to evaluate in field installations, they are also more reliable.

Measurement and Verification

> The ancient Romans had a tradition: whenever one of their engineers constructed an arch, as the capstone was hoisted into place, the engineer assumed accountability for his work in the most profound way possible: he stood under the arch.
> *Michael Armstrong*

Measurement and verification (M&V) provide diagnostic information so that systems continuously realize their intended benefits. The International Performance Measurement and Verification Protocol (www.IPMVP.org) describes options for structuring and implementing such a program. The task of designing the M&V system should be included in the system design, so that measurement instruments can be installed along with the building's systems, and adequate space and connections can be provided. This task is most often added to the mechanical or electrical requirements.

Determining Costs and Fees

How Much Should I Spend?

Sustainable design and consulting services, like the actual buildings, should be cost-effective. For Federal buildings, cost-effectiveness is defined in 10 CFR 436 as a savings-to-investment ratio greater than 1 during a 40-year analysis period for building measures, as opposed to the shorter 25-year analysis period for mechanical equipment measures. This means that it is important to be practical about the extent to which a project can support the cost of consulting and analysis services for sustainability.

It is equally important to be realistic about the extent of the benefits that can be expected as a result of applying these services. This is true whether the analysis is being conducted internally or by outside contractors or consultants. A rule of thumb is that Federal building managers spend as much as one year's expected energy savings for new building energy analysis studies. For major renovations that include window replacements, insulation retrofits, and lighting changes, this rule of thumb is also valid. For minor renovations involving component changes such as fixture or ballast replacements, it is prudent to limit expenditures on energy studies to not more than one-half of one year's expected energy savings.

There is a clear relationship between the level of energy analysis you can afford and the deliverables and level of detail you can expect from the analysis. The following list can help you determine the level of effort you can expect from your energy design professional or your energy consultant.

Modest Effort: 3 to 15 Person-Days *(less than $10,000)*

At this level, your contractor or consultant might be expected to—

- Attend a preliminary meeting and present results at a second meeting.
- Help define energy targets (in both dollars and Btu/ft^2) during programming by running a design-phase analysis tool such as *ENERGY-10* or Energy Scheming.
- With the project architect or manager, use similar tools to study schematic building envelope and massing alternatives, including such options as daylighting, night cooling, passive solar heating, and glazing optimization during the early phases of design.
- Be available to the project architect or manager throughout the design process to answer questions.
- In one- or two-zone buildings, analyze a limited number of simplified HVAC configurations.

- Provide a brief, written final report summarizing recommendations.

Intermediate Effort: 3 to 12 Person-Weeks *(between $10,000 and $40,000)*

At this level, your contractor or consultant might be expected to—

- Attend regular meetings during the design and design development phases.
- Help define energy targets (in both dollars and Btu/ft^2) during programming.
- With the project architect or manager, run DOE-2.2, BLAST, or an equivalent hour-by-hour simulation tool to study schematic building envelope and massing alternatives, including such options as daylighting, shading, lighting controls, and glazing optimization during the early phases of design.
- Be available to the project architect or manager throughout the design process to answer questions.
- Analyze a significant number of alternative HVAC configurations, including controls and distribution options, during design development.
- Conduct an economic analysis of building design and systems alternatives, including life-cycle costs or discounted paybacks.
- Provide a comprehensive, written final report summarizing recommendations.

Large Effort: 2 to 6 Person-Months *(more than $40,000)*

At this level, your contractor or consultant might be expected to:

- Attend regular meetings throughout the project.
- Help define energy targets (in both dollars and Btu/ft^2) during programming.
- With the project architect or manager, run DOE-2.1E, BLAST, or an equivalent hour-by-hour simulation tool to study schematic building envelope and massing alternatives, including such options as daylighting, shading, lighting controls, and glazing optimization during the early phases of design.
- Be available to the project architect or manager throughout the design process to answer questions.
- Maintain an ongoing energy analysis of the evolving design to inform the designers of the energy implications of design alternatives.

- Analyze a significant number of alternative HVAC configurations, including controls and distribution options.
- Conduct a comprehensive economic analysis of building design and systems alternatives, including life-cycle costs or discounted paybacks. Many Federal agencies require that at least three alternative HVAC systems be analyzed on a life-cycle basis.
- In some cases, help write or compile a building commissioning handbook.
- In major renovation projects, conduct physical tests of existing conditions such as infiltration studies, thermography, and equipment efficiency studies.
- Undertake higher order prediction studies, such as physical daylight study models of prototypical office spaces or computational fluid dynamic models of convective flows in atria.
- Team with a utility to analyze utility interface issues such as off-peak ice thermal storage and other peak-shaving and peak-shifting strategies.
- Monitor actual building performance.
- Produce comprehensive intermediate and final reports, as appropriate.

Should I Consider Performance-Based Fees?

Although this practice is far from business-as-usual, several projects have piloted the concept of basing the professional fees on the level of performance as designed. Such performance-based fees reward efforts to minimize a project's life-cycle cost and reward designers for not oversizing equipment.

The elements of a performance-based fee include these:

- A clear goal and a specification as to how performance relative to that goal is to be measured
- A schedule of how the fee is a function of success in meeting the goal
- A method of evaluating the design
- A protocol for resolving disputes without expensive litigation.

To mitigate the risk associated with this approach, some projects have retained a minimum fee and based a special incentive fee on documented performance of the design (Charles Eley, Eley and Associates, San Francisco, CA). However, some efforts to develop performance-based fee contracts have been scuttled by contracting officers or legal advisors unfamiliar with the technology required to evaluate performance. To make this approach work, it is essential to include legal counsel in the earliest stages of contract development. In multiple cases, Federal legal staff have determined that it is not possible to alter the fee structure described in the original solicitation to a performance-based fee through a contract modification.

Conclusion

The procurement of architectural and engineering services is the best place to leverage the resources of an entire project toward increased resource efficiency. Designers respond to what the customer asks for, and careful statements of work and deliverables for A/E teams are the best places in which owners can tell the design community that they want green buildings.

Requests for proposals that require green design services will enhance design firms' interest. Owners sometimes say that they want a green building, but then they do not include the additional tasks or budget to allow the design team to pursue that goal. The statement of work, and its accompanying estimate of the budget, are necessary precursors to a successful green building project.

A low-energy building is not simply the product of new hardware; it is the product of better design. Creating a low-energy building requires comprehensive attention to detail throughout the design process. Even after the building is constructed and properly commissioned, effective post-occupancy analysis is necessary to ensure that expected performance has been achieved.

Studies show that buildings designed with energy consumption in mind by knowledgeable design teams significantly outperform average buildings. Getting and staying involved, and taking a proactive stance, can accomplish a lot. The directives and criteria you set early in the programming and project development phases will have a crucial impact on your building's energy effectiveness.

Glossary

ADELINE (includes SUPERLITE and RADIANCE)—A software tool for daylighting design that links daylighting and thermal performance.

algorithm—A step-by-step procedure for solving a problem or accomplishing some end; the underlying equations that govern a calculation procedure.

ASEAM—A simplified energy analysis software tool based on the bin method of calculating annual performance. It is not set up to properly evaluate the interactive effects of many passive solar features such as daylighting and thermal mass, however.

bins—Groupings of temperature, usually in 5ºF increments centered on a reference value. For example, the 62º temperature bin for a particular climate represents the number of hours during the year when temperatures fall between 59.5º and 64.5ºF.

BLAST—A detailed, annual energy performance software tool that can model the interactive effects of passive solar design strategies such as daylighting, passive solar heating, and thermal mass.

consumption, energy—The actual energy consumed by a building—compare with "load."

correlation—An analysis technique whereby building energy performance is calculated by comparing or correlating the performance of the building in question with prevalidated equations (or curves) based on key thermal characteristics and climate information.

daylighting—The intentional, controlled use of natural light to reduce the requirement for artificial lighting in a building.

DOE-2.1E—An energy analysis software program that calculates the hour-by-hour energy use of a building, given detailed information on the building's location, construction, operation, and heating, ventilating, and air-conditioning systems. It was developed by Lawrence Berkeley National Laboratory in collaboration with Los Alamos National Laboratory and is supported by the U.S. Department of Energy.

elimination parametrics—An analysis procedure that involves zeroing out individual load components, such as artificial lighting, to evaluate the effects of that component on total building loads or energy consumption.

ENERGY-10—An hour-by-hour, annual simulation program designed to analyze residential and commercial buildings of less than about 10,000 ft^2 (or two zones). It was conceived to be used during the earliest phases of design, and was developed by the National Renewable Energy Laboratory with support from the U.S. Department of Energy.

hour-by-hour simulation—An analysis approach that calculates the energy loads and consumption of a building for each hour of the year. Examples of hour-by-hour simulation software include DOE-2.1E and *ENERGY-10*.

LEED—Leadership in Energy and Environmental Design, a rating system devised by the U.S. Green Buildings Council.

load—The net hourly heat loss or heat gain from a structure that must be met by a heating system to achieve interior comfort conditions.

passive solar design—A whole-building, integrated approach to energy design that minimizes loads and uses standard elements of a building, such as windows, walls, and floors, to collect, store, and release the sun's energy for heating, cooling, and lighting.

Trace—A proprietary equipment-sizing program developed by the Trane Corporation.

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